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**FINAL REPORT**

**Grant No.: F49620-98-1-0096**

**Project Title:**

**Experiments and Modeling of High Strain Rate Effects in  
Sands and Clays**

**Principal Investigator:**

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**February 10, 1999**

# **Experiments and Modeling of High Strain Rate Effects in Sands and Clays**

by

**Poul V. Lade**

## **Objectives:**

The objectives of the proposed research program are to obtain experimental stress-strain data over a range of confining pressures and loading velocities, and to develop and verify a comprehensive time dependent model for soils base on the results of the experimental phase. This model will capture time effects, such as loading rate effects, creep, and relaxation, as well as any combination of these, which are all required for realistic modeling of projectile penetration into soils. Testing will be conducted under both drained and undrained boundary conditions to simulate in-situ conditions where soil is located above and below the ground water table. Testing will also be conducted on both sands and clays to fully explore cohesionless and cohesive soil types. The experimental program will consist of four separate programs that will be performed at different confining pressures and loading velocities. The four different programs are associated with different types of experimental equipment, some at different geographical locations.

All experimental work will be either directly support or provide verification for the constitutive modeling effort, and that portion to be conducted at Johns Hopkins University consists of experiments with confining pressures ranging from 0.05 to 0.7 Mpa and low to moderate loading velocities (0.0001 to 0.4 meters/second).

The proposed constitutive modeling program will utilize the data obtained from the experimental program to develop a 4-D constitutive model that includes 3 geometric dimensions (stresses and strains in 3-D) and one dimension of time. This will include a version (based upon experimental data) of the "overstress" model into an existing 3-D constitutive model for frictional materials. This will be accomplished by adding time-dependent parameters into the failure criterion and the work-hardening relation of the existing elasto-plastic model.

## **Status of Effort:**

(1) Experimental Studies: The experimental phase of the study of rate dependent behavior of soils has progressed as planned. The sand has been chosen such that it will exhibit time effects at relatively low confining pressures. After some experimentation, granulated gypsum was rejected due anomalous time behavior. Crushed coral sand was found to have suitable properties for the project. The experimental setup for triaxial testing under controlled conditions has been assembled. Three levels of temperature control are involved in the experimental setup, thus guaranteeing that all experiments will be performed within 1°C of each other.

A series of triaxial tests with constant confining pressure have been finished with 5 different deformation rates, and experiments have been performed in which the deformation rate is changed abruptly from fast to slow and from slow to fast. Experiments are presently in progress to study creep following different stress histories, and a series of relaxation experiments following a similar scheme as that used for the creep testing will be performed. In addition, a series of one-dimensional compression tests with creep studies performed at different stress magnitudes is being conducted.

**Accomplishments/New Findings:**

The experimental phase has progressed as planned with reestablishment of known behavior characteristics, and the project is now just coming to the point where new observations and realizations are on the verge of appearing.

**Publications and Interactions:**

No publications or interactions have been produced from this project yet.

**Termination of Project:**

The project was unfortunately terminated in September 1998.